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A Review on Roughhead Grenadier (*Macrourus berglax*) Biology and Population Structure on Flemish Cap (NAFO Division 3M), 1991-2001 Based on Flemish Cap Survey data.

by

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ABSTRACT

The European Union has conducted since 1988 an annual bottom trawl survey in Flemish Cap (NAFO Div. 3M) in the 200-720 m depth range. The information on roughhead grenadier population structure recorded during the last 11 EU surveys (1991-2001) in Flemish Cap is studied. Depth distribution of captures, length/age distribution of captures, growth rates, sex-ratios, catch curves, and total biomass estimated by the swept area method are presented.

Age and length composition of the catches showed clear differences between the two sexes. The importance of males in the capture declines in larger fish, disappearing from the capture in largest length classes. The bulk of captures in 2001 survey is composed of ages 10, in comparison with ages 7-8 for all the period studied. Both sexes are fully recruited at age 8, and total mortality was estimated as 0.25 for females and 0.49 for males.

The oldest male found was 20 years old, while oldest female was 19 years old. Results show that *M. berglax* has a prolonged life cycle and multiaged population structure with differences in growth and mortality between males and females.

INTRODUCTION

The roughhead grenadier (*Macrourus berglax* Lacépède, 1802) is an abundant and widespread fish species in the north Atlantic and is usually found both on the shelf and on the continental slope (Scott and Scott, 1988; Savvatimsky, 1994). It is predominant in depths ranging from 400 to 1200 m, although they may inhabit depths between 200-2000 m (Snelgrove and Haedrich, 1985; de Cardenas *et al*., 1996), and it has been found in depths up to 2700 m (Wheeler, 1969).

Roughhead grenadier is becoming an important commercial fish in NAFO Regulatory Area and reliable information is needed for its assessment. The fishery for *M. berglax* is unregulated as it has been mainly taken as by-catch in Greenland halibut fishery. Catches of roughhead grenadier increased sharply from 1989 (333 tons) to 1990 (3 244 tons), since then total catches has been about 4,000 tons taken primarily by EU-Portugal and EU-Spain as by-catch in the fishery directed to Greenland halibut. Catches of roughhead grenadier in 1998 increased to 7,200 tons, and remained in this level in 1999.

Since 1988 EU has conducted an annual random-stratified bottom trawl survey in Flemish Cap (NAFO Div. 3M) in the 200-720 m depth range. The objective of this scientific survey is to obtain abundance indices and to study the population structure and biological parameters of the main species in the area.

Limited information on age structure and growth rate of *M. berglax* is available in scientific literature. Savvatimsky (1971, 1984, 1989, 1994) and Jorgensen (1996) have carried out studies on this species in the NW Atlantic (NAFO Div. 0,2GHJ, 3K and 1ABCD, respectively), basing findings on age readings from scales. The age structure and growth parameters of roughhead grenadier have been estimated by Casas (1994), Sainza (1996), Alpoim (1997), Sarasua *et al*., (1998 and 1999), Murua *et al*., (1999) and Murua (2000 and 2001) from otolith readings of specimens captured in NAFO Div. 3LM. Validation of age estimates derived from otolith reading has been presented by Rodríguez-Marín *et al*. (2002). Eliassen (1983) also performed age estimation by otolith reading from roughhead caught in the continental slope of Norway.

This paper presents some biological data and population structure of roughhead grenadier in Flemish Cap durin the period 1991-2001. The results are presented taking into account that the survey only covers the shallowest distribution area of *M. berglax*.

MATERIAL AND METHODS

Data on *M. berglax* for the 1991-2001 period were collected on the annual random-stratified bottom trawl surveys carried out by the European Union on the area (methodology is described by Vázquez, 2002). Data on age structure and sex-ratio are only available for the 1994-2001 period. Otolith sampling began in 1994, and since then a total of 3933 otoliths have been read. Annual length-age keys have been applied for each year. For years when otoliths were not sampled the mean 96-97 age-length key (the most consistent readings) were applied.

Otoliths were broken through the nucleus and read by transmited light (Casas, 1994). Many difficulties in reading Macrouridae age from otoliths and scales have been reported previously (Savvatimsky, 1984). Age reading in larger fish (more than 9 years old) is even more complicated, because many rings are present and they lie close to each other. Nevertheless, intercalibration of readings between three readers has been done and 80% of agreement has been reached. Differences were $\pm$ 1 year in otoliths between 2-10 years and 1, 2 years in older than 10 years (Rodríguez-Marín *et al*., 2002).

Individuals were measured from tip of snout to base of first anal-fin ray, in 0.5 cm intervals, as adopted by NAFO in June 1980 (Atkinson, 1991) as a standard measurement for roundnose and roughhead grenadiers. Length is presented as pre-anal-fin length (AFL) and data are given in 1 cm intervals. Total weight was recorded accurate to the nearest 10 g.

In 1999, 2000 and 2001 was made a comparison between different gears (Lofoten *vs* Campelen), but data presented here concerns only to data gathered by Lofoten gear, which has been the standard net used in previous Flemish Cap cruises.

RESULTS AND DISCUSSION

Total biomass of roughhead grenadier estimated by the swept area method by strata are presented in Table 1 and for the whole bank in Figure 1. Biomass increased from 1989 to 1993, since then the biomass has decreased steadily, with the exception of 1998 year, up to 2000, and in 2001 total biomass increased again reaching the second highest level of 2 473 tones in the period studied. Mean catch per trawl by strata and whole bank data are presented in Table 2. The results indicate that roughhead grenadier occupy the deepest part of the area studied and the abundance and biomass increase with depth, as is evidenced by other authors (de Cardenas *et al*., 1996).

Table 3 shows length distributions of roughhead grenadier for the 1991-2001 period. Captures are dominated by the 14-20 cm length classes, 55 % of the total catch. The average AFL for both sexes is 15,6 cm. This value is smaller than the values found by Savvatimsky (1994) and de Cardenas *et al*. (1996). The former gives an average AFL of 19.8 cm (51.25 cm total length) for Div. 3K, and the latter gives a mean AFL of 21,12 cm (54,39 cm TL) for specimens caught in a long-line survey in Div. 3LMN. These differences are related to the fishing gear employed and depth where fish were caught, because length has a tendency to increase with depth, from the shallowest stratum to the deepest (Cárdenas *et al*., 1996).

Annual length frequencies by sex are presented in Fig. 2. The importance of males in the capture declines in larger fish and they disappear from the capture in largest length classes. Largest male found in the scientific surveys

was 24 cm while females are larger reaching 35 cm long. Average AFL for females is also greater than for males. Female's mean AFL for the 1993-2001 period in Flemish Cap was 16.97 cm, while mean AFL for males was 15.37 cm. This sexual difference is consistent with data found in the literature. Savvatimsky (1989) gives an average AFL of 18 cm (47 cm total length) and 21.2 cm (54.6 cm total length) for males and females respectively in Div. 3LKN. Those differences have also been seen in the commercial fleet in Div. 3LN, where females are larger than males (Junquera et al., 2001).

The mean AFL-age key for 1994-2001, as well as mean length at age and standard deviation are given by sex in Table 4. Mean length at age is similar for males and females for ages under 9 years, but males grow slower from this length onwards. Mean lengths at age are higher than those obtained by Savvatimsky (1994) for NAFO Div. 0B, 2GH and 3K. Savvatimsky (1994) and Jorgensen (1996) described similar growing pattern using scales for aging fish, they found that the differences between sexes in size at age come about from 10 years onwards. This fact could be explained due to the different aging method used in their studies and in ours, or due to different latitude of the sampling areas where specimens were obtained, because temperature differences would cause slower growth, and a delay in reaching sexual maturity (Rodríguez-Marín *et al*., 2002).

Table 5 shows age composition by sexes for *Macrourus berglax* in Flemish Cap in 1993-2001. The oldest male found in the study period was 20 years old, while oldest female was 19 years old. Mean age for females in Flemish Cap in the 1993-2001 period was 8.3 years, while mean age for males was 7.4 years. Savvatimsky (1994) for Div. 0B, 2GH and 3K found similar differences.

Interannual differences in length and age are shown in Fig. 2 and 3. The 1984-1986 cohorts dominated the catches during the first years. The importance of these annual classes have declined sharply during last 4 years and the 1990-91 cohorts now dominates captures. The strength of this year-class has been seen in previous surveys (Alpoim, 1997; Sarasua *et al*., 1998; Sarasua *et al*., 1999; Murua, 2001) and it has been confirmed by the 2001 survey.

Female-ratio in the whole study period is 51%. This value is lower that the one found by de Cardenas *et al*. (1996) in Div. 3LMN, where females made up 71,4% of the catch. However, this difference could be easily explained due to the different area covered by both surveys. As length increases with depth in many species (Cárdenas *et al*., 1996; Junquera *et al*., 1992), female ratio might also increase in deeper areas.

Figures 4 and 5 present sex-ratio by age and by length respectively, for the whole study period. In the sex-ratio, female proportion fluctuates around 40%-50% the first 10-12 years (up to 22 cm in length). It increases from age 13 (length 20 cm) upwards. Female-proportion reaches 75 % in year-group 13 (20 cm) and 80% in year-group 14 (24 cm). Females are 100% of the captures after that. Similar sex-ratio, with males being more abundant in the central part of the population, is described by Savvatimsky (1994) for Northwestern Atlantic.

The increment in the female-ratio can be due to three different reasons: sexual differences in growth rate, in mortality or a combination of both. In this case, there are certainly sexual differences in growth, which are reflected in the mean length at age (Rodríguez-Marín *et al.,* 2002) and in the different growth curves presented in this study.

Von Bertalanffy growth curves and logarithmic regression lines (Fig. 6), fitted to mean length at age by sex, show that males growth rate declines when reaching 18 cm long, around 9 years old, while females do not decline growing until reaching 34-35 cm, around 20 years old. This result was also observed by Savvatimsky (1994), Jorgensen (1996) and Rodríguez-Marín *et al* (2002). Table 6 shows the estimated parameters of the Von Bertalanffy equations and the equations for logarithmic growth regression curves for all the period studied.

On the other hand, it seems that there are some differences in mortality between both sexes, since males disappear from the capture in larger length-classes; this phenomenon has been also observed for other species, i.e. Greenland halibut (Cárdenas, 1996). Total mortality by sex was calculated from catch curves, fitting regression lines by sex to ages fully recruited to the fishery. The catch curve (Fig. 7) was elaborated from data for eight years (1994-2001). Both sexes are fully recruited at age 8, and in fact a different mortality is obtained: 0.25 for females and 0.49 for males.

Length-weight relationship by sex are shown in Table 7 for all the years studied. The relationship between fish length (AFL) and fish weight was assumed to be adequately expresses by the exponential function. Figure 8 shows the length-weight relationship for sexes combined in 2001 survey.

Data available show that *M. berglax* has a prolonged life cycle and multiaged population structure with differences in growth and mortality between males and females. The complex multy-mode length structure and a slow growth is characteristic of deepwater fishes, including grenadiers (Hureau *et al*., 1979; Casas, 1994; Savvatimsky, 1994). All this results must be taken with care due to the small proportion of the roughhead grenadier distribution area covered by the survey.

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Table 1.- Total biomass of roughhead grenadier estimated by the swept area method by strata during the EU bottom survey (1988-2001).

		Biomass estimated by the swept area meted (tons)											
Strata	Depth (m)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1 – 6	125-252						10	26					
7	253-360			0								3	
8	253-360		1					13	3		8		19
9	253-360		6	33	25	4	25	182	22	48	54	35	35
10	253-360							7	1		21	81	21
11	253-360										3	9	7
12	261-540	47	129	119	491	65	150	55	163	66	227	96	281
13	261-540	21	21	71	22	38	89	6	22	93	109	60	138
14	261-540	127	101	165		87	80	321	92	231	161	123	347
15	261-540	35	76	62	382	98	214	100	82	120	86	122	71
16	541-720	252	273	514	1586	622	305	472	251	482	179	268	402
17	541-720	37	214	146		117	153	32	138	243	114	80	440
18	541-720	170	423	256		900	492	183	267	225	372	260	456
19	541-720	325	344	510	1089	419	336	223	383	504	153	109	257
TOTAL		**1014**	**1587**	**1878**	**3595**	**2350**	**1855**	**1619**	**1425**	**2014**	**1488**	**1249**	**2473**
SOP		574	1537	1634	1775	2258	1844	1497	1411	1914	1400	1264	2370
Mean Length (cm)			16.03	15.04	15.31	16.45	15.04	15.24	15.81	15.13	16.04	16.3	16.0
Mean Age					8.1	7.4	6.5	7.6	8.0	7.8	8.0	8.1	8.0

Table 2.- Mean catch per trawl by strata and whole bank (1991-2001).

			Average weight per trawl (Kg.)										
Strata	Area	Depth (m)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1 – 6	467	125-252					0.16	0.68					
7	108	253-360		0.01								0.05	
8	82	253-360	0.02					0.26	0.06		0.14		
9	34	253-360	0.26	1.46	0.94	0.2	1.02	6.52	0.87	2.03	2.15	1.54	0.39
10	128	253-360						0.09	0.02		0.28	1.13	1.45
11	107	253-360									0.06	0.15	0.29
12	90	261-540	2.47	2.31	8.79	1.08	3.12	1.08	3.04	1.28	4.19	1.91	0.11
13	31	261-540	1.16	3.36	1.13	2.01	4.85	0.33	1.18	4.83	5.05	3.09	5.57
14	72	261-540	2.08	3.61		1.87	1.69	6.4	1.92	5.07	3.52	2.66	7.25
15	85	261-540	1.59	1.29	6.78	1.84	4.09	2	1.58	2.32	1.61	2.24	1.40
16	82	541-720	5.33	9.48	29.26	11.72	6.21	9.93	5.1	9.39	3.59	5.26	8.44
17	23	541-720	13.9	6.67		6.29	8.85	1.9	8.18	13	5.81	4.85	26.60
18	22	541-720	25.1	16.52		40.03	28.38	1	16.95	13.37	20.85	16.75	28.50
19	54	541-720	10.8	15.46	29.13	12.71	10.52	6.84	12.21	15.09	4.49	3.43	8.04
Weighted averaged per trawl (Kg)			1.94	2.20	3.94	2.47	2.24	1.94	1.75	2.38	1.71	1.53	3.08
Nº of valid tows			117	117	101	116	121	117	117	119	117	120	120

Table 3.- Roughhead grenadier length distribution and mean AFL (,000) for each year of the 1991-2001 period.

AFL (cm)/Year	91	92	93	94	95	96	97	98	99	00	01	Proportion (%)
3	7	29	0	0	0	7	7	113	21	7	147	0,83
4	14	104	104	0	37	59	35	33	18	33	27	1,28
5	24	321	379	47	45	215	16	95	27	71	229	3,84
6	33	82	120	31	46	63	52	65	24	49	80	2,34
7	77	120	515	65	60	31	111	57	17	38	81	2,87
8	25	57	226	169	72	56	98	66	23	38	149	2,30
9	41	37	112	98	139	46	76	208	35	65	74	2,15
10	40	36	182	231	342	113	94	177	93	27	57	3,15
11	97	49	156	196	295	116	31	121	205	86	95	3,19
12	215	53	200	117	527	160	173	155	102	105	133	4,38
13	253	98	177	100	271	255	195	217	141	145	161	4,66
14	275	259	307	255	131	308	395	496	190	171	388	7,03
15	208	298	560	236	185	212	317	577	324	127	402	7,97
16	221	256	890	213	275	308	208	489	447	295	442	9,40
17	271	187	715	426	332	244	90	345	394	296	392	8,49
18	315	197	613	469	412	244	127	197	330	218	524	8,41
19	266	155	505	440	433	308	163	215	201	224	444	7,46
20	226	210	364	248	280	270	148	159	142	146	356	5,79
21	86	112	282	166	151	114	107	144	128	103	209	3,53
22	81	81	193	101	73	101	113	157	47	88	93	2,50
23	45	74	244	71	16	31	83	50	55	37	80	1,82
24	31	35	95	73	26	46	82	88	32	39	86	1,43
25	0	35	50	72	26	21	45	68	39	37	104	1,25
26	22	62	78	43	19	29	52	38	0	37	46	1,05
27	16	29	31	24	28	21	53	23	9	8	49	0,68
28	25	29	58	8	13	8	22	7	14	13	64	0,66
29	16	21	58	46	0	0	15	23	8	7	16	0,57
30	16	44	17	19	9	8	0	17	25	7	45	0,58
31	0	10	0	31	6	7	7	0	0	7	15	0,21
32	0	14	0	11	7	14	8	0	0	0	8	0,15
33	0	0	0	0	0	0	0	0	0	0	0	0,00
34	0	0	0	0	0	0	0	7	0	8	0	0,03
35	0	0	0	0	0	0	0	0	0	7	0	0,01
Total	**2946**	**3094**	**7231**	**4006**	**4256**	**3415**	**2923**	**4407**	**3091**	**2539**	**4996**	**100**
Mean AFL (cm)	**16,03**	**15,04**	**15,31**	**16,45**	**15,04**	**15,24**	**15,81**	**15,13**	**16,04**	**16,14**	**16.00**	**15,61**

Table 4.- Mean Age-Length key (1994-2001).

Males

Length / Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		20	Total
3	8	1																	**9**
4	2	5																	**7**
5		14																	**14**
6		15	9																**24**
7		1	16																**17**
8		3	18	5															**26**
9		1	19	20	1														**41**
10			7	28	9														**44**
11			2	24	28	2													**56**
12			1	4	34	20	7												**66**
13				2	19	36	16												**73**
14					15	37	23	11	1										**87**
15					2	25	30	20	6										**83**
16					3	17	39	31	24	6	1								**121**
17						9	23	28	25	24	2								**111**
18						1	10	28	29	27	16	3	3		1				**118**
19							6	13	27	29	21	11	4	2	1				**114**
20								3	17	21	14	25	7	2					**89**
21								1	9	6	12	17	7	3	1	2			**58**
22										2	2	4	2	2				1	**13**
23													1	2			1		**4**
24														1				1	**2**
Total	**10**	**40**	**72**	**83**	**111**	**147**	**154**	**135**	**138**	**115**	**68**	**60**	**24**	**12**	**3**	**2**	**1**	**2**	**1177**
%	**0,8**	**3,4**	**6,1**	**7,1**	**9,4**	**12,5**	**13,1**	**11,5**	**11,7**	**9,8**	**5,8**	**5,1**	**2,0**	**1,0**	**0,3**	**0,2**	**0,1**	**0,2**	**100**
Mean Length	**3,2**	**5,6**	**8,1**	**10,1**	**12,2**	**14,1**	**15,4**	**16,7**	**17,9**	**18,5**	**19,3**	**20,1**	**20,2**	**21,3**	**19,3**	**21,0**	**23,0**	**23,0**	**15,1**
St. Dv.	**0,42**	**1,22**	**1,36**	**1,09**	**1,40**	**1,49**	**1,70**	**1,55**	**1,64**	**1,37**	**1,26**	**0,96**	**1,31**	**1,60**	**1,53**			**1,41**	

Table 4.- (continued)

Females	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	4																				**4**
4		9																			**9**
5		24																			**24**
6		17	10																		**27**
7		11	30																		**41**
8		2	31	8																	**41**
9			20	20	3																**43**
10			10	35	11																**56**
11			1	25	26	3															**55**
12				11	28	21	1	1													**62**
13				1	32	32	9	1	1												**76**
14					16	34	22	8													**80**
15					4	32	28	20	4	1											**89**
16					2	16	32	25	11	3											**89**
17						8	30	29	18	3											**88**
18							13	27	25	14											**79**
19							3	22	36	23	7	2									**93**
20								8	29	30	17	5									**89**
21								4	12	27	16	7	4								**70**
22									4	17	28	18	11	3							**81**
23									2	2	15	11	11	2	2						**45**
24									1	5	10	16	15	7	2						**56**
25										1	6	8	14	14	4	1					**48**
26										1	1	12	9	3	7	3					**36**
27										1	1	1	8	8	8	1	1				**29**
28													3	10	5	2	1				**21**
29												1	1	1	4	5		1			**13**
30											1		1	4	6		4				**16**
31															2	1		2		1	**6**
32												1		1	1	1	1				**5**
34																1		1			**2**
35																			1		**1**
Total	**4**	**63**	**102**	**100**	**122**	**146**	**138**	**145**	**143**	**128**	**102**	**82**	**77**	**53**	**41**	**15**	**7**	**4**	**1**	**1**	**1474**
%	**0,3**	**4,3**	**6,9**	**6,8**	**8,3**	**9,9**	**9,4**	**9,8**	**9,7**	**8,7**	**6,9**	**5,6**	**5,2**	**3,6**	**2,8**	**1,0**	**0,5**	**0,3**	**0,1**	**0,1**	**100**
M. AFL	**3,0**	**5,6**	**7,9**	**10,1**	**12,2**	**14,0**	**15,7**	**17,1**	**18,7**	**20,2**	**22,0**	**23,4**	**24,4**	**26,1**	**27,4**	**28,5**	**29,6**	**31,3**	**35,0**	**31,0**	**17,0**
St. Dv.		**1,04**	**1,17**	**1,14**	**1,45**	**1,46**	**1,51**	**1,80**	**1,79**	**1,94**	**1,89**	**2,22**	**2,01**	**2,25**	**2,23**	**2,45**	**1,62**	**2,06**			

Table 5.- Roughhead grenadier age composition (,000) in Flemish Cap 1993-2001.

	1993			1994			1995			1996			1997		
Age	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**
2		8	8		9	9	20	38	58	46	24	70	14	21	35
3	112	248	359	17	36	53	92	104	196	35	79	114	83	149	232
4	173	162	335	143	121	264	190	247	437	116	84	200	53	106	159
5	120	151	271	108	139	247	360	443	803	149	172	321	73	89	162
6	445	207	652	187	101	288	324	259	583	365	194	559	214	230	444
7	621	570	1190	224	104	328	385	180	565	191	157	348	284	309	593
8	437	413	850	169	134	303	343	240	583	232	127	359	59	110	169
9	309	353	663	124	160	284	162	192	354	167	85	252	71	111	182
10	278	257	535	42	133	175	41	111	152	199	127	326	78	63	141
11	248	327	575		113	113		39	39	226	97	323	74	130	204
12	128	205	334	28	50	78		33	33	68	52	120	103	127	230
13	69	149	218		47	47		27	27	15	34	49	44	110	154
14	6	62	67					7	7		44	44	15	55	70
15		85	85		22	22		22	22		5	5		56	56
16		31	31								14	14		18	18
18+														18	18
Total	**2946**	**3228**	**6174**	**1042**	**1169**	**2211**	**1917**	**1942**	**3859**	**1809**	**1295**	**3104**	**1165**	**1702**	**2867**
M. Age	**7,79**	**8,39**	**8,10**	**6,79**	**7,93**	**7,39**	**6,33**	**6,57**	**6,45**	**7,62**	**7,60**	**7,61**	**7,60**	**8,24**	**7,98**
S.D.	**2,37**	**3,10**	**2,79**	**1,93**	**2,88**	**2,54**	**1,76**	**2,56**	**2,20**	**2,53**	**3,09**	**2,78**	**2,84**	**3,60**	**3,33**

	1998			1999			2000			2001			Total		
Age	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**	**M**	**F**	**Tot**
1	26	13	39	10	0	10	0	0	0	62	13	75	98	26	124
2	63	130	193	0	36	36	30	62	92	170	161	331	343	489	832
3	119	135	254	20	34	54	61	46	107	94	185	279	633	1016	1648
4	125	121	246	128	81	209	43	29	72	54	80	134	1025	1031	2056
5	90	49	139	108	83	191	106	124	230	111	128	239	1225	1378	2603
6	141	201	342	92	153	245	145	142	287	214	245	459	2127	1732	3859
7	411	322	733	303	143	446	111	114	225	270	266	536	2800	2165	4964
8	549	410	959	383	278	661	149	125	274	287	231	518	2608	2068	4676
9	125	155	280	274	210	484	260	159	419	325	264	589	1817	1689	3507
10	156	120	276	131	113	244	169	187	356	339	480	819	1433	1591	3024
11	101	73	174	87	55	142	19	67	86	83	214	297	838	1115	1953
12	99	149	248	48	59	107	43	78	121	76	94	170	593	847	1441
13	60	147	207	25	49	74	15	51	66	8	97	105	236	711	947
14	34	68	102	35	47	82	12	40	52	8	132	140	110	455	564
15		61	61	5	39	44	8	22	30	7	61	68	20	373	393
16		31	31		4	4	31	29	60	8	98	106	39	225	264
17		15	15											15	15
18+														18	18
Total	**2099**	**2200**	**4299**	**1649**	**1384**	**3033**	**1202**	**1275**	**2477**	**2116**	**2749**	**4865**	**15945**	**16944**	**32889**
M. Age	**7,53**	**8,12**	**7,83**	**7,92**	**8,19**	**8,04**	**7,92**	**8,34**	**8,14**	**7,33**	**8,47**	**7,97**	**7,44**	**8,03**	**7,75**
S.D.	**2,74**	**3,58**	**3,21**	**2,35**	**2,96**	**2,65**	**2,87**	**3,30**	**3,11**	**2,56**	**3,29**	**2,98**	**2,56**	**3,29**	**2,98**

Table 6a. Logarithmic growth regression curves, fitted to mean length at age data, for male and female roughhead grenadier from EU Survey (1993-2001).

	MALES			FEMALES		
Year	**t_o**	**L_∞**	**K**	**t_o**	**L_∞**	**K**
2001	0,950	23.9	0.159	0,350	52,3	0,051
2000	0,199	25.8	0,128	-0,079	68,7	0,034
1999	-0,132	27,9	0,104	0,405	57,8	0,044
1998	0,270	27,5	0,109	0,460	46,3	0,056
1997	1,425	22,9	0,176	0,533	51,2	0,050
1996	0,490	23,5	0,172	0,346	77,0	0,032
1995	-1,576	37,1	0,073	-0,681	51,9	0,053
1994	1,768	22,8	0,254	-0,054	57,6	0,048
1993	1,074	21,9	0,197	0,634	46,4	0,060

Table 6b.- Parameters of the Von Bertalanffy growth curves by sex for the EU Survey 1993-2001.

	MALES		FEMALES	
Year	Regression	r^2	Regression	r^2
2001	AFL (cm) = 7,266*Ln (A) + 1,4463	0.975	AFL (cm) = 10,291* Ln (A) - 1,9577	0.9422
2000	AFL (cm) = 7.835 * Ln (A) – 0.0057	0.9896	AFL (cm) = 12.923 * Ln (A) – 7.6958	0.9331
1999	AFL (cm) = 7.4754 Ln (A) + 1.1001	0.9621	AFL (cm) = 9.6124 * Ln (A) - 1.1061	0.9240
1998	AFL (cm) = 7.1799 Ln (A) + 1.3319	0.9678	AFL (cm) = 9.5935 * Ln (A) - 1.4863	0.9183
1997	AFL (cm) = 8.7078 Ln (A) - 1.6519	0.9925	AFL (cm) = 12.118 * Ln (A) - 6.4209	0.9546
1996	AFL (cm) = 8.9440 Ln (A) - 1.6428	0.9911	AFL (cm) = 12.241 * Ln (A) - 6.1702	0.9551
1995	AFL (cm) = 8.8152 Ln (A) - 0.2014	0.9509	AFL (cm) = 12.268 * Ln (A) - 5.1506	0.9503
1994	AFL (cm) = 13.034 Ln (A) - 8.1095	0.9241	AFL (cm) = 12.394 * Ln (A) - 5.4082	0.9412
1993	AFL (cm) = 8.8156 Ln (A) - 1.8999	0.9861	AFL (cm) = 12.999 * Ln (A) - 8.6786	0.9794

Table 7. Length weight relationship for roughhead grenadier males and females from EU Survey (1993-2001).

	MALES		FEMALES	
Year	Regression	r^2	Regression	r^2
2001	W (g) = 0,2747 * AFL (cm)$^{2.5821}$	0.9637	W (g) = 0,1922 * AFL (cm)^{2,716}	0.9859
2000	W (g) = 0.1423 * AFL (cm)$^{2.8148}$	0.9776	W (g) = 0.1708 * AFL (cm)$^{2.7537}$	0.9744
1999	W (g) = 0.1290 * AFL (cm)$^{2.8670}$	0.9718	W (g) = 0.1174 * AFL (cm)$^{2.8950}$	0.9866
1998	W (g) = 0.1338 * AFL (cm)$^{2.8621}$	0.9669	W (g) = 0.1199 * AFL (cm)$^{2.9015}$	0.9866
1997	W (g) = 0.1209 * AFL (cm)$^{2.8840}$	0.9812	W (g) = 0.1202 * AFL (cm)$^{2.8898}$	0.9923
1996	W (g) = 0.1244 * AFL (cm)$^{2.8889}$	0.9802	W (g) = 0.1367 * AFL (cm)$^{2.8536}$	0.9851
1995	W (g) = 0.1131 * AFL (cm)$^{2.9409}$	0.9818	W (g) = 0.1139 * AFL (cm)$^{2.9344}$	0.9859
1994	W (g) = 0.1489 * AFL (cm)$^{2.8437}$	0.9694	W (g) = 0.1015 * AFL (cm)$^{2.9935}$	0.9895
1993	W (g) = 0.0793 * AFL (cm)$^{3.0883}$	0.9734	W (g) = 0.1016 * AFL (cm)$^{2.9934}$	0.9895

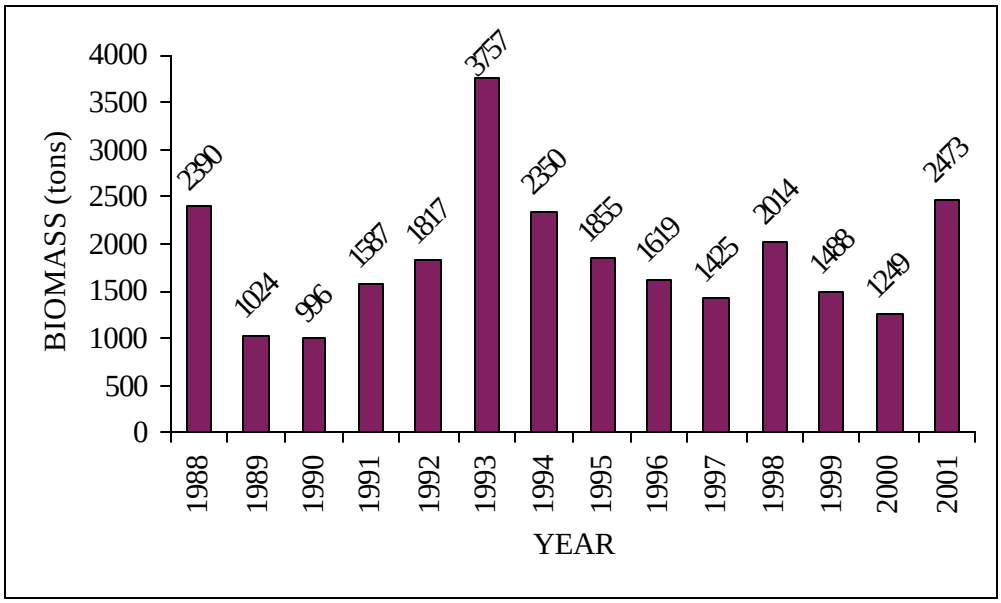


Fig. 1. Total biomass estimated by the swept area method for the area studied during the EU bottom trawl survey (1988-2001).

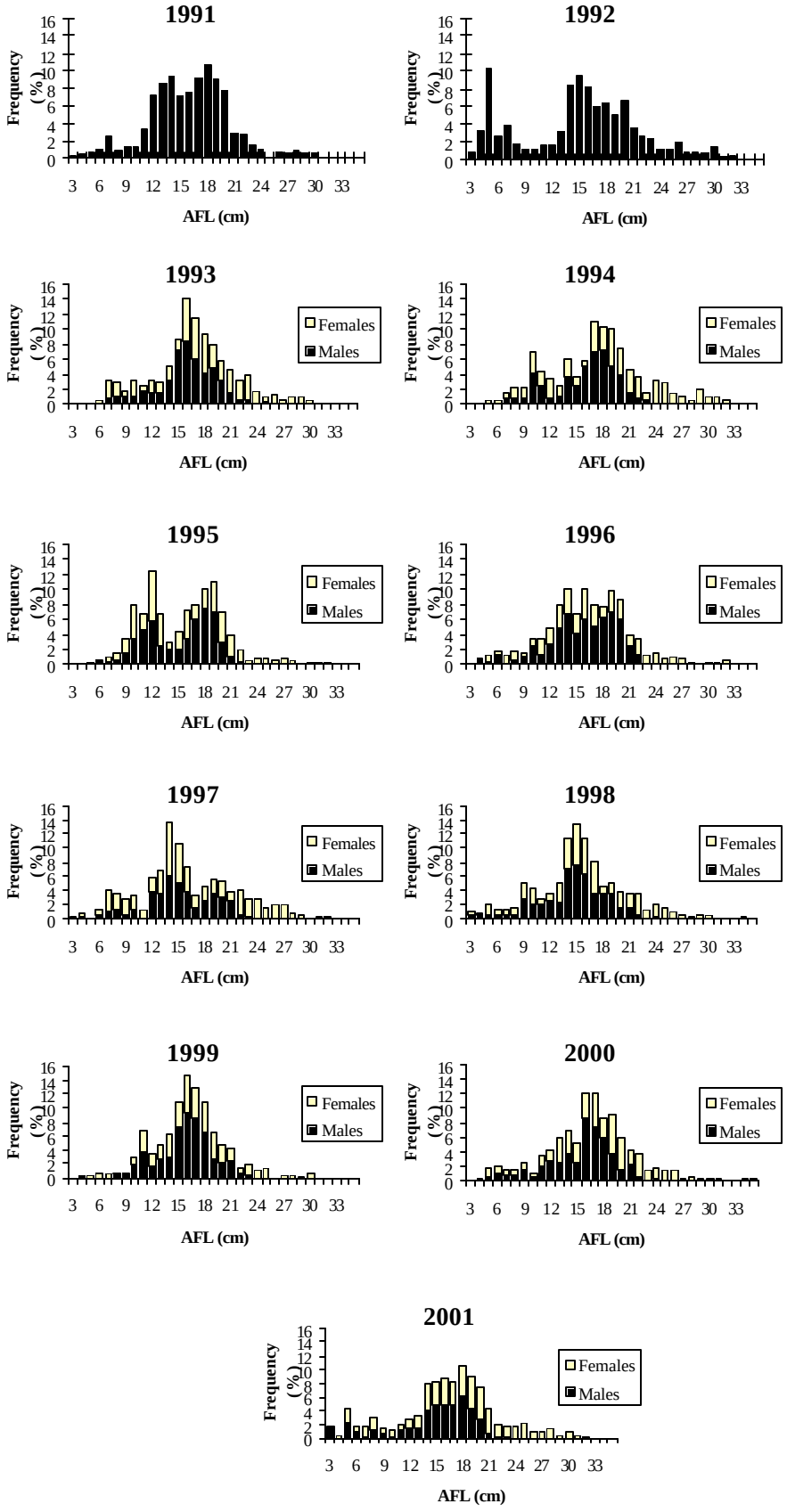


Fig. 2. Annual length distribution by sex (except 1991-1992) in Flemish Cap 1991-2001.

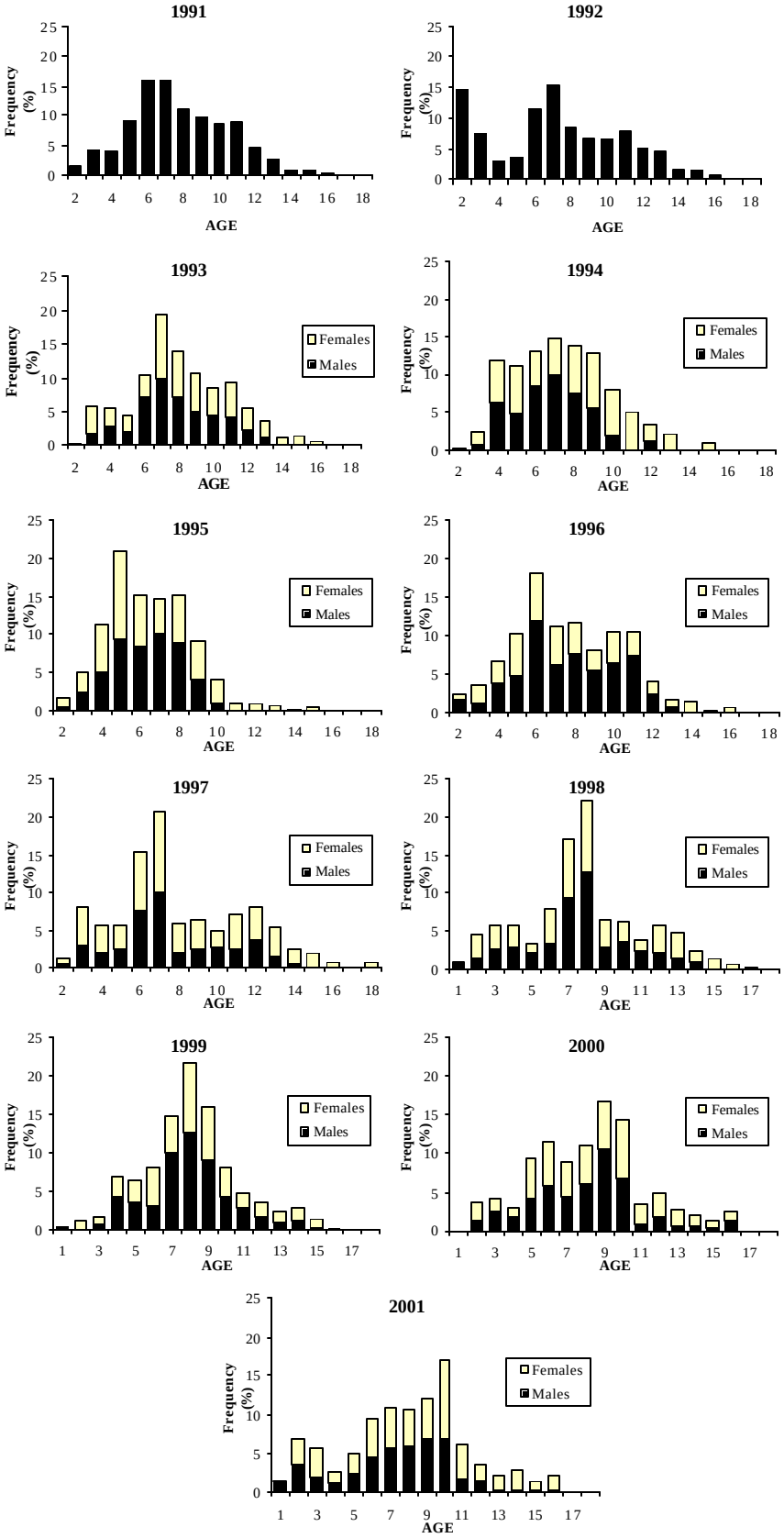


Fig. 3. Annual age composition by sex (except 1991-1992), in Flemish Cap 1991-2001.

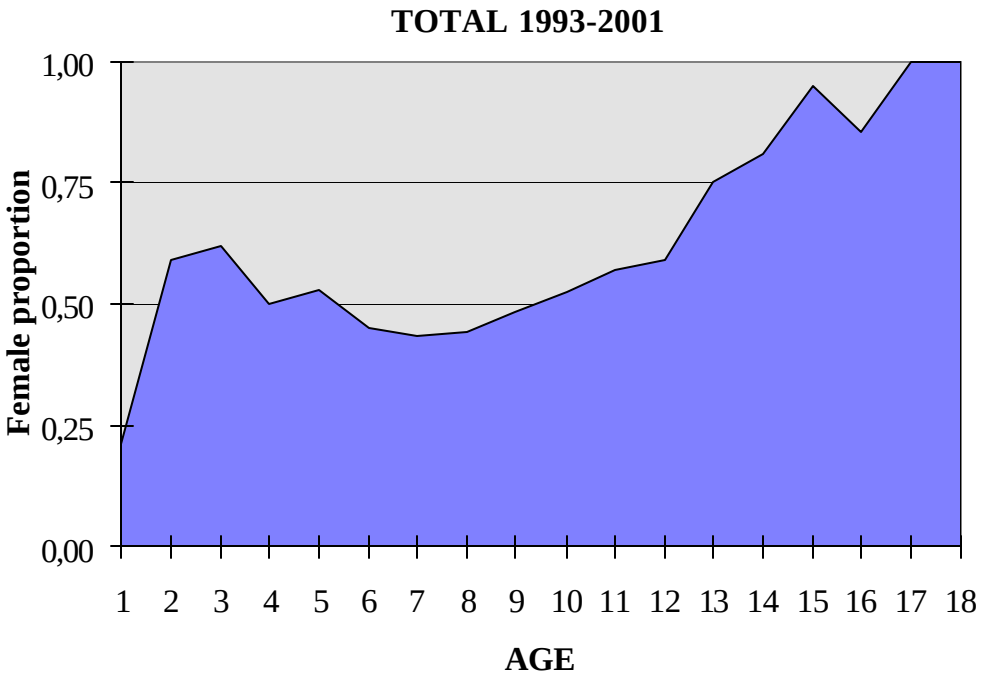


Fig. 4. Female ratio by age in Flemish Cap 1993-2001.

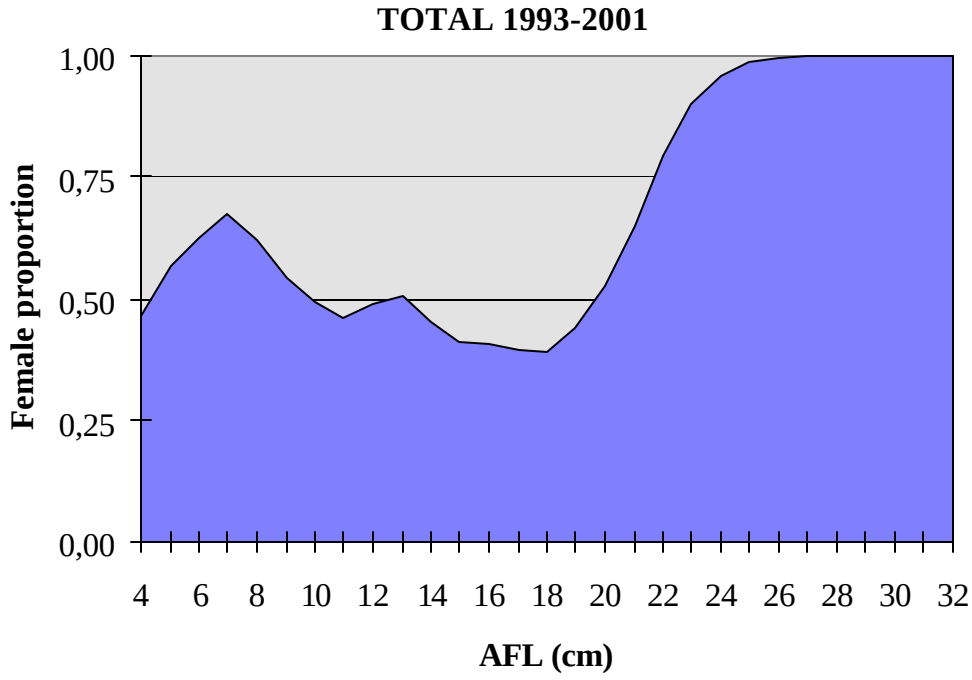
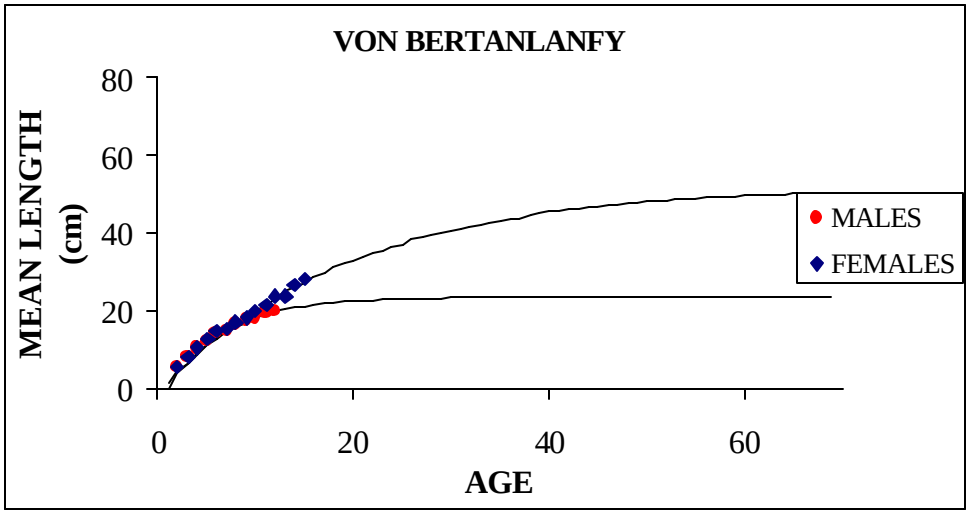


Fig. 5. Female ratio by length in Flemish Cap 1993-2001.

(a)



b)

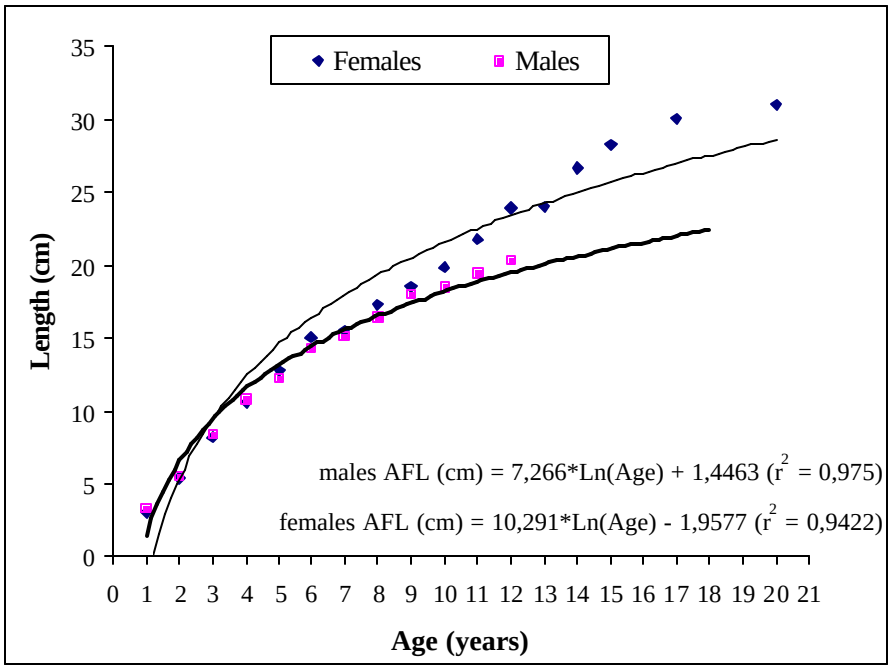


Fig. 6 a and b. Von Bertanlanffy (a) and logarithmic (b) growth curve by sexes in Flemish Cap 2001.

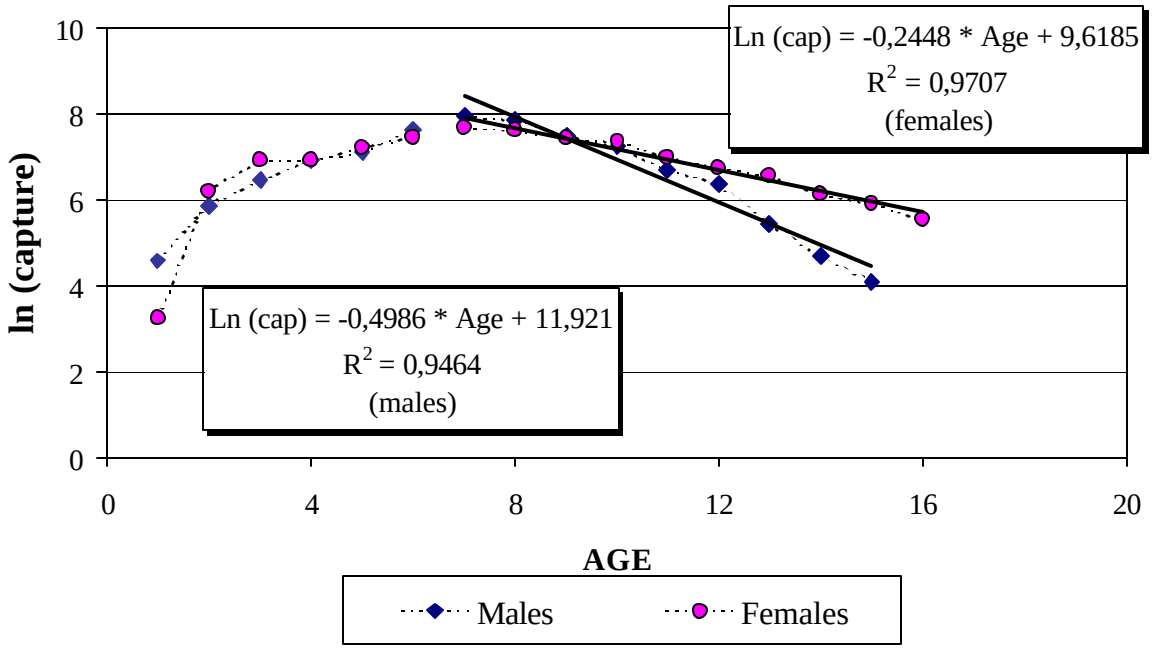


Fig.7. Catch curves by sex for roughhead grenadier in Flemish Cap 1994-2001.

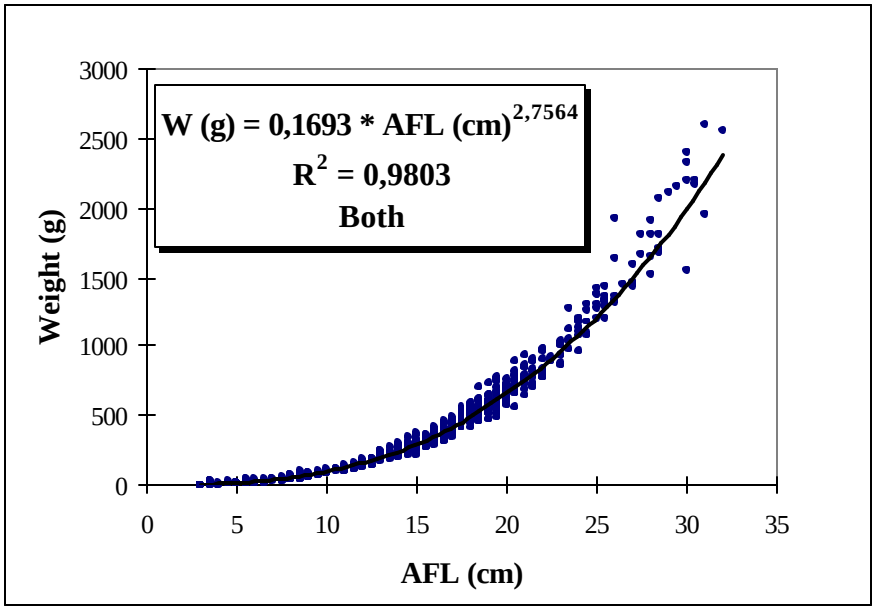


Fig.8. Length weight relationship for both sexes of roughhead grenadier in 2001.